

CLAIMS

What is claimed is:

1. A method for forming one or more particles, the method comprising:

(a) providing a patterned template and a substrate, wherein the patterned template comprises a patterned template surface having a plurality of recessed areas formed therein;

(b) disposing a volume of liquid material in or on at least one of:

(i) the patterned template surface; and

(ii) the plurality of recessed areas; and

(c) forming one or more particles by one of:

(i) contacting the patterned template surface with the substrate and treating the liquid material; and

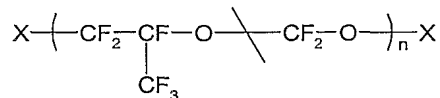
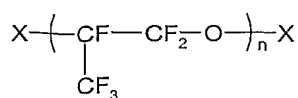
(ii) treating the liquid material.

2. The method of Claim 1, wherein the patterned template comprises a solvent resistant, low surface energy polymeric material.

3. The method of Claim 1, wherein the patterned template comprises a solvent resistant elastomeric material.

4. The method of Claim 1, wherein at least one of the patterned template and substrate comprises a material selected from the group consisting of a perfluoropolyether material, a fluoroolefin material, an acrylate material, a silicone material, a styrenic material, a fluorinated thermoplastic elastomer (TPE), a triazine fluoropolymer, a perfluorocyclobutyl material, a fluorinated epoxy resin, and a fluorinated monomer or fluorinated oligomer that can be polymerized or crosslinked by a metathesis polymerization reaction.

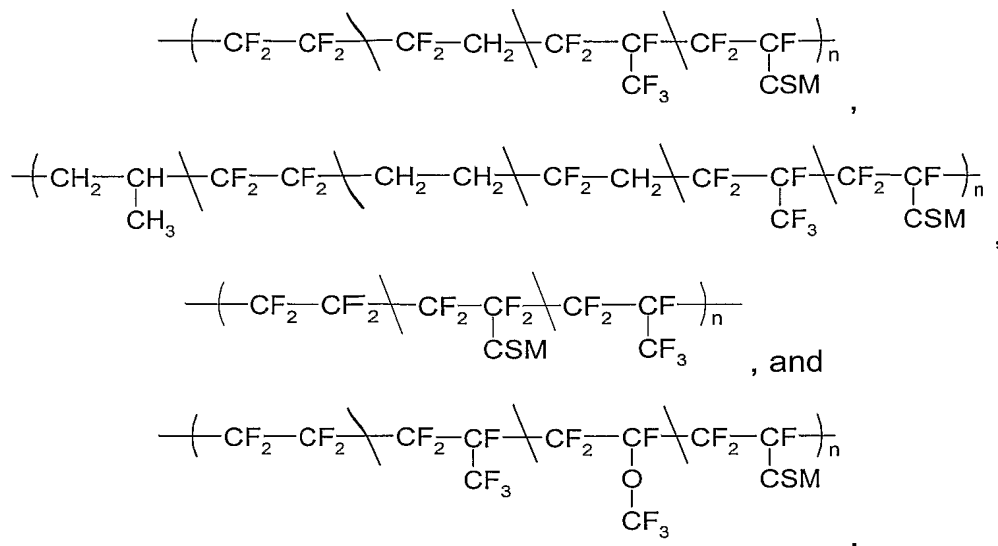
5. The method of Claim 4, wherein the perfluoropolyether material comprises a backbone structure selected from the group consisting of:





wherein X is present or absent, and when present comprises an endcapping group.

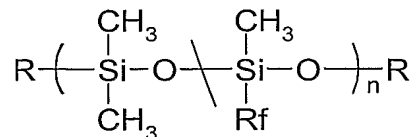
6. The method of Claim 4, wherein the fluoroolefin material is selected from the group consisting of:



wherein CSM comprises a cure site monomer.

7. The method of Claim 4, wherein the fluoroolefin material is made from monomers which comprise tetrafluoroethylene, vinylidene fluoride or hexafluoropropylene. 2,2-bis(trifluoromethyl)-4,5-difluoro-1,3-dioxole, a functional fluoroolefin, functional acrylic monomer, a functional methacrylic monomer.

8. The method of Claim 4, wherein the silicone material comprises a fluoroalkyl functionalized polydimethylsiloxane (PDMS) having the following structure:

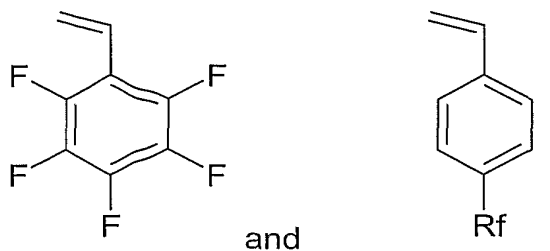


wherein:

R is selected from the group consisting of an acrylate, a methacrylate, and a vinyl group; and

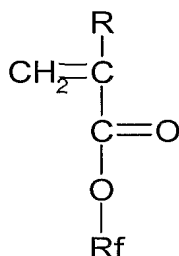
Rf comprises a fluoroalkyl chain.

9. The method of Claim 4, wherein the styrenic material comprises a fluorinated styrene monomer selected from the group consisting of:



wherein Rf comprises a fluoroalkyl chain.

5 10. The method of Claim 4, wherein the acrylate material comprises a fluorinated acrylate or a fluorinated methacrylate having the following structure:



wherein:

10 R is selected from the group consisting of H, alkyl, substituted alkyl, aryl, and substituted aryl; and

Rf comprises a fluoroalkyl chain.

11. The method of Claim 4, wherein the triazine fluoropolymer comprises a fluorinated monomer.

15 12. The method of Claim 4, wherein the fluorinated monomer or fluorinated oligomer that can be polymerized or crosslinked by a metathesis polymerization reaction comprises a functionalized olefin.

13. The method of Claim 12, wherein the functionalized olefin comprises a functionalized cyclic olefin.

20 14. The method of Claim 1, wherein at least one of the patterned template and the substrate has a surface energy lower than 18 mN/m.

15. The method of Claim 1, wherein at least one of the patterned template and the substrate has a surface energy lower than 15 mN/m.

16. The method of Claim 1, wherein the substrate is selected from the group consisting of a polymer material, an inorganic material, a silicon material, a quartz material, a glass material, and surface treated variants thereof.

5 17. The method of Claim 1, wherein the substrate comprises a patterned area.

18. The method of Claim 1, wherein the plurality of recessed areas comprises a plurality of cavities.

10 19. The method of Claim 18, wherein the plurality of cavities comprise a plurality of structural features.

20. The method of Claim 19, wherein the plurality of structural features has a dimension ranging from about 10 microns to about 1 nanometer in size.

15 21. The method of Claim 19, wherein the plurality of structural features has a dimension ranging from about 10 microns to about 1 micron in size.

22. The method of Claim 19, wherein the plurality of structural features has a dimension ranging from about 1 micron to about 100 nm in size.

20 23. The method of Claim 19, wherein the plurality of structural features has a dimension ranging from about 100 nm to about 1 nm in size.

24. The method of Claim 1, wherein the one or more particles are essentially free of a scum layer.

25 25. The method of Claim 1, wherein the patterned template comprises a patterned template formed by a replica molding process.

26. The method of Claim 25, wherein the replica molding process comprises:

- 30 (a) providing a master template;
- (b) contacting a liquid material with the master template; and
- (c) curing the liquid material to form a patterned template.

27. The method of Claim 26, wherein the master template is selected from the group consisting of:

- (a) a template formed from a lithography process;

- (b) a naturally occurring template; and
- (c) combinations thereof.

28. The method of Claim 27, wherein the natural template is selected from one of a biological structure and a self-assembled structure.

5        29. The method of Claim 28, wherein the one of a biological structure and a self-assembled structure is selected from the group consisting of a naturally occurring crystal, a protein, an enzyme, a virus, a micelle, and a tissue surface.

10       30. The method of Claim 1, comprising modifying the patterned template surface by a surface modification step.

31. The method of Claim 30, wherein the surface modification step is selected from the group consisting of a plasma treatment, a chemical treatment, and an adsorption process.

15       32. The method of Claim 31, wherein the adsorption process comprises adsorbing molecules selected from the group consisting of a polyelectrolyte, a poly(vinylalcohol), an alkylhalosilane, and a ligand.

20       33. The method of Claim 1, comprising positioning the patterned template and the substrate in a spaced relationship to each other such that the patterned template surface and the substrate face each other in a predetermined alignment.

25       34. The method of Claim 1, wherein the liquid material is selected from the group consisting of a polymer, a solution, a monomer, a plurality of monomers, a polymerization initiator, a polymerization catalyst, an inorganic precursor, a metal precursor, a pharmaceutical agent, a tag, a magnetic material, a paramagnetic material, a superparamagnetic material, a ligand, a cell penetrating peptide, a porogen, a surfactant, a plurality of immiscible liquids, a solvent, and a charged species.

35. The method of Claim 34, wherein the pharmaceutical agent is selected from the group consisting of a drug, a peptide, RNAi, and DNA.

30       36. The method of Claim 34, wherein the tag is selected from the group consisting of a fluorescence tag, a radiolabeled tag, and a contrast agent.

37. The method of Claim 34, wherein the ligand comprises a cell targeting peptide.

38. The method of Claim 1, wherein the liquid material comprises a non-wetting agent.

5 39. The method of Claim 1, wherein the disposing of the volume of liquid material is regulated by a spreading process.

40. The method of Claim 39, wherein the spreading process comprises:

10 (a) disposing a first volume of liquid material on the patterned template to form a layer of liquid material on the patterned template; and

(b) drawing an implement across the layer of liquid material to:

15 (i) remove a second volume of liquid material from the layer of liquid material on the patterned template; and

(ii) leave a third volume of liquid material on the patterned template.

20 41. The method of Claim 1, wherein the contacting of the patterned template surface with the substrate displaces essentially all of the disposed liquid material from between the patterned template surface and the substrate.

25 42. The method of Claim 1, wherein the treating of the liquid material comprises a process selected from the group consisting of a thermal process, a photochemical process, and a chemical process.

43. The method of Claim 1, further comprising:

(a) reducing the volume of the liquid material disposed in the plurality of recessed areas by one of:

30 (i) applying a contact pressure to the patterned template surface; and

(ii) allowing a second volume of the liquid to evaporate or permeate through the template;

- (b) removing the contact pressure applied to the patterned template surface;
- (c) introducing gas within the recessed areas of the patterned template surface;
- 5 (d) treating the liquid material to form one or more particles within the recessed areas of the patterned template surface; and
- (e) releasing the one or more particles.

10 44. The method of Claim 43, wherein the releasing of the one or more particles is performed by one of:

- (a) applying the patterned template to a substrate, wherein the substrate has an affinity for the one or more particles;
- (b) deforming the patterned template such that the one or more particles is released from the patterned template;
- 15 (c) swelling the patterned template with a first solvent to extrude the one or more particles; and
- (d) washing the patterned template with a second solvent, wherein the second solvent has an affinity for the one or more particles.

20 45. The method of Claim 1, comprising harvesting or collecting the particles.

46. The method of Claim 45, wherein the harvesting or collecting of the particles comprises a process selected from the group consisting of scraping with a medical scalpel, a brushing process, a dissolution process, an  
25 ultrasound process, a megasonics process, an electrostatic process, and a magnetic process.

47. The method of Claim 1, wherein the method comprises a batch process.

30 48. The method of Claim 47, wherein the batch process is selected from one of a semi-batch process and a continuous batch process.

49. A particle or plurality of particles formed by the method of Claim 1.

50. The plurality of particles of Claim 49, wherein the plurality of particles comprises a plurality of monodisperse particles.

51. The particle or plurality of particles of Claim 49, wherein the particle or plurality of particles is selected from the group consisting of a semiconductor device, a crystal, a drug delivery vector, a gene delivery vector, a disease detecting device, a disease locating device, a photovoltaic device, a solar cell device, a porogen, a cosmetic, an electret, an additive, a catalyst, a sensor, a detoxifying agent, an abrasive, a micro-electro-mechanical system (MEMS), a cellular scaffold, a taggart, a pharmaceutical agent, and a biomarker.

52. The particle or plurality of particles of Claim 49, wherein the particle or plurality of particles comprise a freestanding structure.

53. The method of Claim 1, comprising forming a multi-dimensional structure, the method comprising:

- (a) providing a particle of Claim 49;
- (b) providing a second patterned template;
- (c) disposing a second liquid material in the second patterned template;
- (d) contacting the second patterned template with the particle of step (a); and
- (e) treating the second liquid material to form a multi-dimensional structure.

54. The method of Claim 1, comprising forming an interconnected structure.

55. The method of Claim 54, wherein the interconnected structure comprises a plurality of shape and size specific holes.

56. The method of Claim 55, wherein the interconnected structure comprises a membrane.

57. A method for delivering a therapeutic agent to a target, the method comprising:

- (a) providing a particle of Claim 49;
- (b) admixing the therapeutic agent with the particle; and



(c) delivering the particle comprising the therapeutic agent to the target.

58. The method of Claim 57, wherein the therapeutic agent is selected from one of a drug and genetic material.

5 59. The method of Claim 58, wherein the genetic material is selected from the group consisting of a non-viral gene vector, DNA, RNA, RNAi, and a viral particle.

60. The method of Claim 59, wherein the particle comprises a biodegradable polymer.

10 61. The method of Claim 60, wherein the biodegradable polymer is selected from the group consisting of a polyester, a polyanhydride, a polyamide, a phosphorous-based polymer, a poly(cyanoacrylate), a polyurethane, a polyorthoester, a polydihydropyran, and a polyacetal.

15 62. The method of Claim 61, wherein the polyester is selected from the group consisting of polylactic acid, polyglycolic acid, poly(hydroxybutyrate), poly( $\epsilon$ -caprolactone), poly( $\beta$ -malic acid), and poly(dioxanones).

20 63. The method of Claim 61, wherein the polyanhydride is selected from the group consisting of poly(sebacic acid), poly(adipic acid), and poly(terphthalic acid).

64. The method of Claim 61, wherein the polyamide is selected from the group consisting of poly(imino carbonates) and polyaminoacids.

25 65. The method of Claim 61, wherein the phosphorous-based polymer is selected from the group consisting of a polyphosphate, a polyphosphonate, and a polyphosphazene.

66. The method of Claim 60, wherein the biodegradable polymer further comprises a polymer that is responsive to a stimulus.

30 67. The method of Claim 66, wherein the stimulus is selected from the group consisting of pH, radiation, ionic strength, temperature, an alternating magnetic field, and an alternating electric field.

68. The method of Claim 67, wherein the stimulus comprises an alternating magnetic field.

69. The method of Claim 57, comprising exposing the particle to an alternating magnetic field once the particle is delivered to the target.

70. The method of Claim 69, wherein the exposing of the particle to an alternating magnetic field causes the particle to produce heat through one of a hypothermia process and a thermo ablation process.

71. The method of Claim 70, wherein the heat produced by the particle induces one of a phase change in the polymer component of the particle and a hyperthermic treatment of the target.

72. The method of Claim 71, wherein the phase change in the polymer component of the particle comprises a change from a solid phase to a liquid phase.

73. The method of Claim 72, wherein the phase change from a solid phase to a liquid phase causes the therapeutic agent to be released from the particle.

74. The method of Claim 73, wherein the release of the therapeutic agent from the particle comprises a controlled release.

75. The method of Claim 57, wherein the target is selected from the group consisting of a cell-targeting peptide, a cell-penetrating peptide, an integrin receptor peptide (GRGDSP), a melanocyte stimulating hormone, a vasoactive intestinal peptide, an anti-Her2 mouse antibody, and a vitamin.

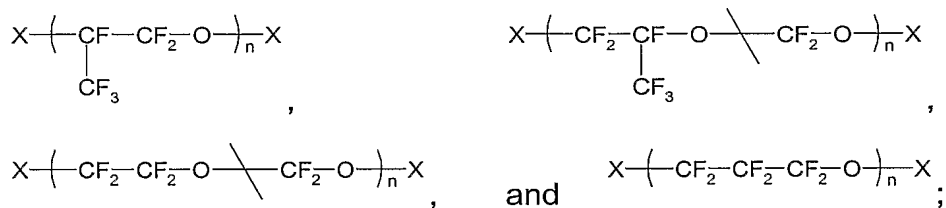
76. A method for forming a pattern on a substrate, the method comprising:

- (a) providing patterned template and a substrate, wherein the patterned template comprises a patterned template surface having a plurality of recessed areas formed therein;
- (b) disposing a volume of liquid material in or on at least one of:
  - (i) the patterned template surface; and
  - (ii) the plurality of recessed areas;
- (c) contacting the patterned template surface with the substrate; and
- (d) treating the liquid material to form a pattern on the substrate.

77. The method of Claim 76, wherein the patterned template comprises a solvent resistant elastomeric material.

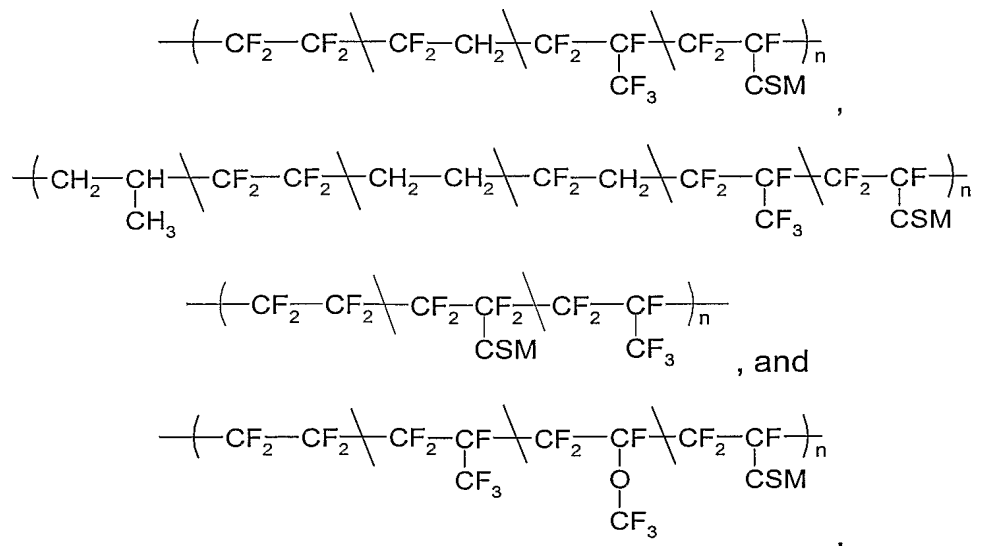
78. The method of Claim 76, wherein at least one of the patterned template and substrate comprises a material selected from the group consisting of a perfluoropolyether material, a fluoroolefin material, an acrylate material, a silicone material, a styrenic material, a fluorinated thermoplastic elastomer (TPE), a triazine fluoropolymer, a perfluorocyclobutyl material, a fluorinated epoxy resin, and a fluorinated monomer or fluorinated oligomer that can be polymerized or crosslinked by a metathesis polymerization reaction.

79. The method of Claim 78, wherein the perfluoropolyether material comprises a backbone structure selected from the group consisting of:



wherein X is present or absent, and when present comprises an endcapping group.

80. The method of Claim 78, wherein the fluoroolefin material is selected from the group consisting of:

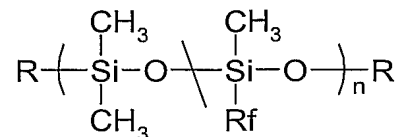


wherein CSM comprises a cure site monomer.

81. The method of Claim 78 wherein the fluoroolefin material is made from monomers which comprise tetrafluoroethylene, vinylidene fluoride

or hexafluoropropylene. 2,2-bis(trifluoromethyl)-4,5-difluoro-1,3-dioxole, a functional fluoroolefin, functional acrylic monomer, a functional methacrylic monomer.

82. The method of Claim 78, wherein the silicone material comprises a fluoroalkyl functionalized polydimethylsiloxane (PDMS) having the following structure:

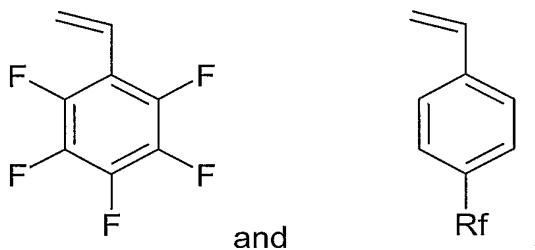


wherein:

R is selected from the group consisting of an acrylate, a methacrylate, and a vinyl group; and

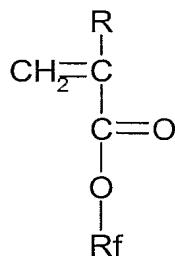
Rf comprises a fluoroalkyl chain.

83. The method of Claim 78, wherein the styrenic material comprises a fluorinated styrene monomer selected from the group consisting of:



wherein Rf comprises a fluoroalkyl chain.

84. The method of Claim 78, wherein the acrylate material comprises a fluorinated acrylate or a fluorinated methacrylate having the following structure:



wherein:

R is selected from the group consisting of H, alkyl, substituted alkyl, aryl, and substituted aryl; and

R<sub>f</sub> comprises a fluoroalkyl chain.

5        85. The method of Claim 78, wherein the triazine fluoropolymer comprises a fluorinated monomer.

86. The method of Claim 78, wherein the fluorinated monomer or fluorinated oligomer that can be polymerized or crosslinked by a metathesis polymerization reaction comprises a functionalized olefin.

10       87. The method of Claim 86, wherein the functionalized olefin comprises a functionalized cyclic olefin.

88. The method of Claim 76, wherein at least one of the patterned template and the substrate has a surface energy lower than 18 mN/m.

89. The method of Claim 76, wherein at least one of the patterned template and the substrate has a surface energy lower than 15 mN/m.

15       90. The method of Claim 76, wherein the substrate is selected from the group consisting of a polymer material, an inorganic material, a silicon material, a quartz material, a glass material, and surface treated variants thereof.

20       91. The method of Claim 76, wherein the substrate is selected from one of an electronic device in the process of being manufactured and a photonic device in the process of being manufactured.

92. The method of Claim 76, wherein the substrate comprises a patterned area.

25       93. The method of Claim 76, wherein the plurality of recessed areas comprises a plurality of cavities.

94. The method of Claim 93, wherein the plurality of cavities comprise a plurality of structural features.

30       95. The method of Claim 94, wherein the plurality of structural features has a dimension ranging from about 10 microns to about 1 nanometer in size.

96. The method of Claim 94, wherein the plurality of structural features has a dimension ranging from about 10 microns to about 1 micron in size.

97. The method of Claim 94, wherein the plurality of structural features has a dimension ranging from about 1 micron to about 100 nm in size.

98. The method of Claim 94, wherein the plurality of structural features has a dimension ranging from about 100 nm to about 1 nm in size.

99. The method of Claim 76, wherein the liquid material is selected from the group consisting of a polymer, a solution, a monomer, a plurality of monomers, a polymerization initiator, a polymerization catalyst, an inorganic precursor, a metal precursor, a pharmaceutical agent, a tag, a magnetic material, a paramagnetic material, a superparamagnetic material, a ligand, a cell penetrating peptide, a porogen, a surfactant, a plurality of immiscible liquids, a solvent, and a charged species.

100. The method of Claim 99, wherein the pharmaceutical agent is selected from the group consisting of a drug, a peptide, RNAi, and DNA.

101. The method of Claim 99, wherein the tag is selected from the group consisting of a fluorescence tag, a radiolabeled tag, and a contrast agent.

102. The method of Claim 99, wherein the ligand comprises a cell targeting peptide.

103. The method of Claim 76, wherein the liquid material is selected from one of a resist polymer and a low-k dielectric

104. The method of Claim 76, wherein the liquid material comprises a non-wetting agent.

105. The method of Claim 76, wherein the disposing of the volume of liquid material is regulated by a spreading process.

106. The method of Claim 105, wherein the spreading process comprises:

- (a) disposing a first volume of liquid material on the patterned template to form a layer of liquid material on the patterned template; and
- (b) drawing an implement across the layer of liquid material to:
  - (i) remove a second volume of liquid material from the layer of liquid material on the patterned template; and

- (ii) leave a third volume of liquid material on the patterned template.

107. The method of Claim 76, wherein the contacting of the first template surface with the substrate eliminates essentially all of the disposed volume of liquid material.

108. The method of Claim 76, wherein the treating of the liquid material comprises a process selected from the group consisting of a thermal process, a photochemical process, and a chemical process.

109. The method of Claim 76, comprising a batch process.

110. The method of Claim 109, wherein the batch process is selected from one of a semi-batch process and a continuous batch process.

111. A patterned substrate formed by the method of Claim 76.

112. An apparatus for forming one or more particles, the apparatus comprising:

- (a) a patterned template and a substrate, wherein the patterned template comprises a patterned template surface having a plurality of recessed areas formed therein;
- (b) a reservoir for disposing a volume of liquid material in or on at least one of:
  - (i) the patterned template surface; and
  - (ii) the plurality of recessed areas; and
- (c) a controller for forming one or more particles by one of:
  - (i) contacting the patterned template surface with the substrate and treating the liquid material; and
  - (ii) treating the liquid material.

113. The apparatus of Claim 112, further comprising an inspecting device for one of inspecting, measuring, and both inspecting and measuring one or more characteristics or the one or more particles.

114. An apparatus for forming a pattern on a substrate, the apparatus comprising:

- (a) a patterned template and a substrate, wherein the patterned template comprises a patterned template surface having a plurality of recessed areas formed therein;
- (b) a reservoir for disposing a volume of liquid material in or on at least one of:
  - (i) the patterned template surface; and
  - (ii) the plurality of recessed areas;
- (c) a controller for forming the pattern on the substrate by:
  - (i) contacting the patterned template surface with the substrate; and
  - (ii) treating the liquid material.

115. The apparatus of Claim 114, further comprising an inspecting device for one of inspecting, measuring, and both inspecting and measuring one or more characteristics of the pattern on the substrate.

116. A method of forming a pattern on a surface, the method comprising selectively exposing the surface of an article to an agent by:

- (a) shielding a first portion of the surface of the article with a masking system, wherein the masking system comprises a elastomeric mask in conformal contact with the surface of the article; and
- (b) applying an agent to be patterned within the masking system to a second portion of the surface of the article, while preventing application of the agent to the first portion shielded by the masking system.

117. The method of Claim 116, wherein the elastomeric mask comprises a plurality of channels.

118. The method of Claim 117, wherein each of the channels has a cross-sectional dimension of less than about 1 millimeter.

119. The method of Claim 117, wherein each of the channels has a cross-sectional dimension of less than about 1 micron.

120. The method of Claim 116, wherein the agent swells the elastomeric mask less than about 25%.



121. The method of Claim 116, wherein the agent comprises an organic electroluminescent material or a precursor thereof.

122. The method of Claim 121, further comprising:

- (a) allowing the organic electroluminescent material to form from the agent at the second portion of the surface, and
- (b) establishing electrical communication between the organic electroluminescent material and an electrical circuit.

123. The method of Claim 116, wherein the agent comprises the product of a deposition process, wherein the deposition process is selected from the group consisting of a chemical vapor deposition process, a gas phase deposition process, an electron-beam deposition process, an electron-beam evaporation process, an electron-beam sputtering process, and an electrochemical deposition process.

124. The method of Claim 116, wherein the agent comprises a product of electroless deposition.

125. The method of Claim 116, wherein the agent is applied from a fluid precursor.

126. The method of Claim 125, wherein the fluid precursor is selected from the group consisting of a solution of an inorganic compound, a suspension of an inorganic compound, a suspension of particles in a fluid carrier, and a chemically active agent in a fluid carrier.

127. The method of Claim 116, wherein the inorganic compound hardens on the second portion of the article surface.

128. The method of Claim 126, further comprising allowing the fluid carrier to dissipate thereby depositing the particles at the first region of the article surface.

129. The method of Claim 126, further comprising allowing the fluid carrier to dissipate thereby depositing the chemically active agent at the first region of the article surface.

130. The method of Claim 126, wherein the chemically active agent comprises a polymer precursor.

131. The method of Claim 130, further comprising forming a polymeric article from the polymer precursor.

132. The method of Claim 126, wherein the chemically active agent comprises an agent capable of promoting deposition of a material.

5           133. The method of Claim 126, wherein the chemically active agent comprises an etchant.

134. The method of Claim 116, further comprising allowing the second portion of the surface of the article to be etched.

10           135. The method of Claim 116, further comprising removing the elastomeric mask of the masking system from the first portion of the article surface while leaving the agent adhered to the second portion of the article surface.